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MOTION OF AN ELECTRIC ARC IN A TRANSVERSE MAGNETIC FIELD, (U)  
JUN 77 Y V BOYKO, V T CHERMERIS

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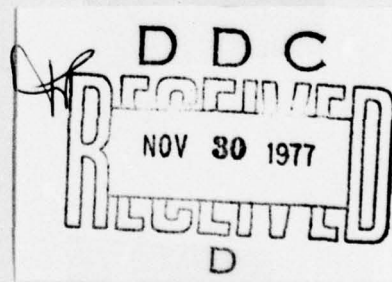
## FOREIGN TECHNOLOGY DIVISION



MOTION OF AN ELECTRIC ARC IN A TRANSVERSE MAGNETIC  
FIELD

by

Yu. V. Boyko, V. T. Chemeris



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# UNEDITED MACHINE TRANSLATION

FTD-ID(RS)T-1010-77

24 June 1977

MICROFICHE NR: *FTD-77-C-000754*

CSI76271823

MOTION OF AN ELECTRIC ARC IN A TRANSVERSE MAGNETIC FIELD

By: Yu. V. Boyko, V. T. Chemeris

Source: Teplotekhnicheskiye Problemy Pryamogo  
Preobrazovaniya Energii, Izd-vo, "Naukova  
Dumka, Kiev, No. 2, 1971, PP. 95-102

Country of origin: USSR

This document is a machine translation

Requester: AFAPL/POD

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Block	Italic	Transliteration	Block	Italic	Transliteration
А а	<b>А а</b>	A, a	Р р	<b>Р р</b>	R, r
Б б	<b>Б б</b>	B, b	С с	<b>С с</b>	S, s
В в	<b>В в</b>	V, v	Т т	<b>Т т</b>	T, t
Г г	<b>Г г</b>	G, g	У у	<b>У у</b>	U, u
Д д	<b>Д д</b>	D, d	Ф ф	<b>Ф ф</b>	F, f
Е е	<b>Е е</b>	Ye, ye; E, e*	Х х	<b>Х х</b>	Kh, kh
Ж ж	<b>Ж ж</b>	Zh, zh	Ц ц	<b>Ц ц</b>	Ts, ts
З з	<b>З з</b>	Z, z	Ч ч	<b>Ч ч</b>	Ch, ch
И и	<b>И и</b>	I, i	Ш ш	<b>Ш ш</b>	Sh, sh
Й й	<b>Й й</b>	Y, y	Щ щ	<b>Щ щ</b>	Shch, shch
К к	<b>К к</b>	K, k	Ъ ъ	<b>Ъ ъ</b>	"
Л л	<b>Л л</b>	L, l	Ы ы	<b>Ы ы</b>	Y, y
М м	<b>М м</b>	M, m	Ь ь	<b>Ь ь</b>	'
Н н	<b>Н н</b>	N, n	Э э	<b>Э э</b>	E, e
О о	<b>О о</b>	O, o	Ю ю	<b>Ю ю</b>	Yu, yu
П п	<b>П п</b>	P, p	Я я	<b>Я я</b>	Ya, ya

\*ye initially, after vowels, and after ъ, ъ; e elsewhere.  
 When written as ë in Russian, transliterate as yë or ë.  
 The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

## GREEK ALPHABET

Alpha	A	α	α	Nu	N	ν
Beta	B	β		Xi	Ξ	ξ
Gamma	Γ	γ		Omicron	Ο	ο
Delta	Δ	δ		Pi	Π	π
Epsilon	E	ε	ε	Rho	Ρ	ρ ϑ
Zeta	Z	ζ		Sigma	Σ	σ ς
Eta	H	η		Tau	Τ	τ
Theta	Θ	θ	θ	Upsilon	Υ	υ
Iota	I	ι		Phi	Φ	φ φ
Kappa	K	κ	κ	Chi	Χ	χ
Lambda	Λ	λ		Psi	Ψ	ψ
Mu	M	μ		Omega	Ω	ω

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MOTION OF AN ELECTRIC ARC IN A TRANSVERSE MAGNETIC FIELD.

Yu. V. Boyko, V. T. Chemeris

(Institute of the electrodynamics of AS UkSSR, Kiev).

The investigations of the driving arcs in the flow of gas under the action of magnetic field constantly attract the attention of the researchers in connection with the manifold of conditions in different equipment/devices, where is observed this motion, and with the riches of the physical phenomena, it accompanying. Is known a large quantity of investigations of this question, beginning from the studies of the work of arc-suppression equipment/devices [1], also, to the studies of the ionization of inert gas by moving magnetized cord of plasma [2]. But also now not to end/leads are clear such questions: flow of flow about the arc, the birth and the disappearance of charged particles on the boundaries of plasma column, exchange of momentum/impulse/pulse and energy between the components of plasma in a column of arc, etc. [3].

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This work was stimulated by the need for research on the possibilities of designing of equipment/devices of the type of magnetoarcdynamic generator [4], the using the driving flow with alternation cold and ionized layers of gas. At the experimental installation (Fig. 1), which was magnetohydrodynamic rectangular channel (inside measurements 400 x 70 x 10 mm) with continuous copper electrodes, are investigated some special feature/peculiarities of the motion of arc in the flow of the heated gas. The utilized gas (argon) is heated in the plasmotron of direct current, then it mixes itself with the flow of colder argon (to 800°C), which can contain vapors of potassium, and at the duct inlet acquired a temperature of 1100-1300°K at rate 15-20 m/s and on pressure  $10^5$  N/m<sup>2</sup>. The speed of flow at the duct inlet is rate/estimated according to the measured expenditure/consumption and temperature. Temperature was measured by the thermocouple VR5/VR20. The channel is arranged/located in stationary transverse magnetic field 0.35 Tesla. Electrodes do not have special preheating, arc is supplied through supplementary resistor/resistance from dc power supply 560 in, arc currents they do not exceed 10 a. Under conditions of experiment the arc spontaneously ignites at the duct inlet, it moves in channel under the action of

electromagnetic forces with speed of approximately 50 m/s and it is disrupted at output/yield from channel by the combined action of the stray field of electromagnet and flow of gas. The magnetic field of current on electrodes does not affect the motion of arc, since little. For diagnostics are utilized single and dual electroprobes (  $l = 10$  mm, diameter 0.3 mm), that made it possible to judge the character of motion and the size/dimensions of arc stream in central and the adjacent to electrodes fields, and the germanium photodiodes, which recorded the integral emission/radiation of arc through opening/apertures in the anode. On the curves of change in time of the current of dual probes and potential of single probes are analyzed and are compared the special feature/peculiarities of the motion of arc in pure/clean argon and in argon with the additive of potassium.

The conditions of the experiment were selected so that the fundamental factors, determining the special feature/peculiarities of the motion of arc, they will be: 1) the presence or the absence of the being easily ionized additive in flow; 2) the initial concentration of charged particles in flow (their existence caused themes that the flow from plasmatron falls into channel with a sufficiently large potential difference between electrodes); 3) residual phenomena in flow after the passage of the preceded arc (when arcs follow each other).

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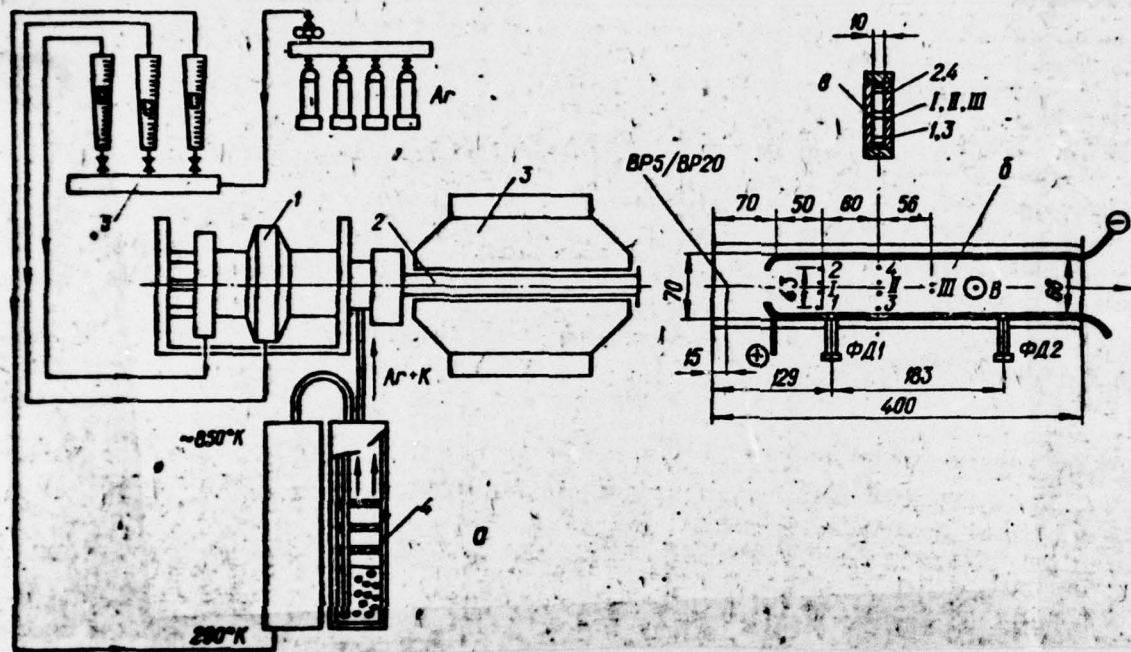


Fig. 1.

Fig. 1. The diagrammatic representation of the fundamental assemblies of the experimental installation: a) the schematic diagram of setting; b) the longitudinal section of channel and the circuit of the arrangement/permutation of sensors; c) the cross section of channel; 1 - plasmatron; 2 - channel; 3 - electromagnet; 4 - the feed system of alkaline additive; 5 - the control system of the gas flow; FD1, FD2 - photodiodes; 1-4 - potential probes; I-III - dual probes.

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Probe measurements under conditions of the described experiment differ in terms of peculiarity. The theory of cylindrical probe in continuous medium (dense weakly ionized gas) [5] makes it possible according to ion saturation current to obtain estimate of the magnitude

$$nD_i \left( 1 + \frac{r_0}{r_i} \right) \cdot I_{i, \text{max}}$$

where  $D_i$  - the coefficient of the diffusion of ions (by effect of magnetic field it is possible to disregard, since  $(\omega r_i) \sim 10^{-4}$ ). This expression is reduced to the form

$$n(\pi r_i)^{3/2} \sim I_{i, \text{max}} / r_0 \cdot \frac{r_0}{r_i}$$

The latter means that for the comprehensive evaluation of the

properties of the driving column it is necessary to conduct the composite measurements of probe current in conjunction with the measurement of the temperatures of electrons and neutral particles with other diagnostic means. In this case it is necessary to consider the presence of considerable its own potential gradient in plasma, where is placed probe (10-30 V/cm), and by the absence of the possibility of monitoring of the saturation of ion current in the changing in time parameters of plasma. We do not attempt to ensure measurement with high accuracy, but is utilized dual probe for recording the torque/moments of the passage of arc and estimate/evaluation of the size/dimensions of the cross section of arc stream. The stress of dual probe selected as being equal to 36 in, which provides the operating mode, close to saturation, and at the same time does not make it possible of the establishment of arc mode/conditions in the interval/gap between probes. In work [6] were removed the volt-amperes characteristic of dual probes in the mixture of gases with the additive of potassium at temperature to 900°K, where reveal/detected a sharp increase in the probe current with a potential difference between probes to 120 in. The curve of probe current (Fig. 2) shows that the maximum of the concentration in arc is displaced in the direction of the motion of arc.

Single probes with dc amplifiers (passband 0-400 Hz, the entry impedance  $3 \cdot 10^6$  ohm) are utilized for the recording of potentials in

the fields, adjacent to electrodes.

At installation were realized three operating modes: 1 - the motion of separate arcs with time interval between them, by somewhat greater than the duration of the passage of channel by arc; 2 - the motion of several arcs after each other without the breaking of current in external circuit; 3 - the repeated motion of arcs, which rapidly led to the unstable mode with pulsating current in channel, not giving possibility to judge the localization of currents and the presence of the driving/moving arcs.

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The effect of the induced during the motion of arc electric field to the processes, which determine this motion, will be insignificant. Curved changes in time of current and stress of arc, current and voltage of dual and single probes and signals of photodiodes are recorded with photographic paper with the aid of magnitoelectric oscillograph at the rate of the motion of paper 2.5 m/s. Oscillograms made it possible to present the process of the establishment of arc in the beginning of its motion. It is natural that the rate of the motion of arc stream is above, when its end/leads still not had time to arrive to motion, but column is bent and is dilate/extended by magnetic field - this is characteristic for

the initial stage of the motion of arc. With the start of an entire arc, including its end/leads, when it completely undergoes transverse blowout the flow of gas, is observed deceleration of its motion and a reduction in current. Some oscillograms correspond to the cases, when breaking of arc occurred in the average/mean section of channel because was impeded the handling of traffic of the end/leads of the arc along electrodes these oscillograms were used to evaluate the character of the motion of the products of arcing right after its break. The obtained from probe measurements estimate/evaluations show that as time on the order of  $10^{-3}$  s the residue/reminders of the decomposing arc stream accept the speed of the circumfluent flow of gas and equalize the degree of ionization to the level, which occurs in flow, but the temperature of ions remains above the temperature of the neutral particles of flow, thanks to which dual probe is capable to record the passage of the heated cloud.

On oscillograms, that relate to the motion of separate arcs, it will be possible to produce the evaluations of the initial state of gas flow. Even in the absence of alkaline additive and in the absence of arc argon in channel will be weakly ionized because of electric field, and the flow is characterized by the completely determined picture of the distribution of potential across it.

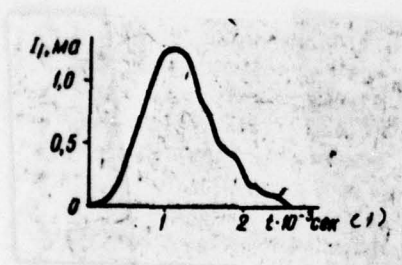


Fig. 2. Curve of probe current (III dual probe).

Key: (1). s.

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In the absence of arc the potentials of single probes comprise in the field near the cathode of approximately 100 V, but in the field near the anode - more than 300 V; the transverse gradient of potential in flow core is 40 V/cm. With a temperature decrease of gas this picture is displaced upward along the axis of the stress with constant/invariable potential gradient in flow core.

Estimate/evaluation of the concentration in flow in the absence of arc of probe current gives value  $n_e \sim 2 \cdot 10^9 \text{ cm}^{-3}$ . The introduction of the

additive of potassium (0.7c/o according to the mass flow rate) increases the electron concentration in flow more than by an order and substantially it changes the initial potential distribution in the flow: the potential of the probe near the anode descends to value of approximately 200 V, the potential of probe in the field near the cathode descends almost by an order, but because of this twice grow/rises the potential gradient in flow core. Undoubtedly, this affects the conditions of developing of arc and its motion, which becomes more uniform, and arc less contracted. Current variation in arc during its motion sharply they decrease. Figure 3 depicts the curve/graphs of the motion of arc in pure/clean argon ( $T = 1300^\circ\text{K}$ ) / the reading of the average speed of arc on the individual sections of channel it conducts on the temporary displacements between the signals of the corresponding probes.

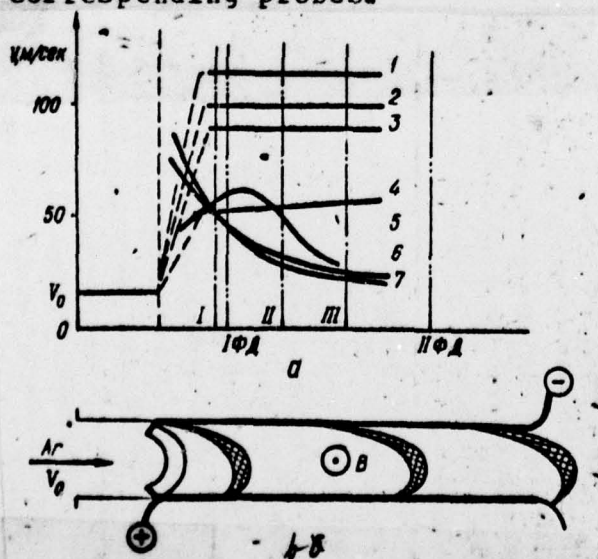


Fig. 3. Distribution of the speeds of arc along the length of channel (a) and the flow chart of arc along electrodes (b) in pure/clean argon with  $T_0 = 1300^\circ\text{K}$  ( $V_0 = 16 \text{ m/s}$ ).

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The driving arc is characterized by the longitudinal electric intensity 10-30 V/cm (high value is related to the initial section of channel), by constant/invariable along the length of channel averaged current density (at the level 1.2 A/cm<sup>2</sup>) and by an increase in the average plasma conductivity in arc stream 4 times of the length of channel. This is related to the cases of the stable onset and motion of arc (curves 1-4). The curves 5-7 illustrate changes in the speed of the arcs whose motion was complicated by the backlash of an increase in the current or by the break of arc stream soon after of its start. Figure 4a shows the curves of the velocities of arc in channel for argon with the additive of potassium (T = 1100°C). The arc is characterized by the averaged current density 1 A/cm<sup>2</sup>, by the strength of the longitudinal electric field 20-30 V/cm. The comparison of the motion of arcs in pure/clean argon and argon with potassium makes it possible to conclude that at identical current densities the levels of the average electrical conductivity of plasma in the driving arc stream are close in value.

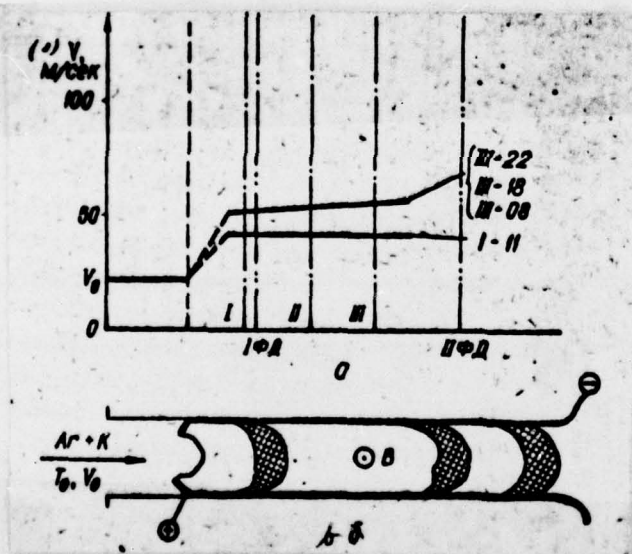


Fig. 4. Distribution of the speeds of arc along the length of channel (a) and the flow chart of arc along electrodes (b) in argon with the additive of potassium (0.70/o) with  $T_0 = 1100^\circ\text{K}$  ( $V_0 = 22 \text{ m/s}$ ).

Key: (1). m/s.

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The speed of the motion of arc relative to flow and the value of arc current for pure/clean argon in this case is twice as more as; the motion of arc in argon with potassium is characterized by the high constancy of speed and cross section of arc stream. The presence of the additive of potassium delays the processes of deionization, and the restoration/reduction of potential in flow after the passage of arc strongly it is involve/tightened. In the case of pure/clean argon this backlash can be connected only with the powerful curvature of arc stream in the field near the cathode due to the delay of the motion of the cathode spot, connected with its inertness (time, required for the establishment of cathode spot on copper electrode, it composes approximately  $10^{-3}$  s [1], i.e., about 1/3 transit times by the arc of entire length of channel). The introduction of an additive of potassium facilitates the process of the displacement/movement of cathode spot, which we were judged by a decrease in the temporary displacements between the onsets of signals on the probes, arranged/located in just one section of channel, and by the more uniform wear of the surface of the electrode of that served

as cathode.

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4. TITLE (and Subtitle) MOTION OF AN ELECTRIC ARC IN A TRANSVERSE MAGNETIC FIELD		5. TYPE OF REPORT & PERIOD COVERED Translation
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Yu. V. Boyko, V. T. Chemeris		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Foreign Technology Division Air Force Systems Command U. S. Air Force		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE 1971
		13. NUMBER OF PAGES 14
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